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(पहला पुनरीक्षण)

Indian Standard

DESIGN AND CONSTRUCTION OF BOX TYPE FORGING FURNACES — GUIDELINES

(First Revision)

ICS 25.180

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

October 1998

Price Group 3

Industrial Fuel-Fired Furnaces Sectional Committee, MTD 26

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Industrial Fuel-Fired Furnaces Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1981. While reviewing the standard in the light of experience gained during these years, the committee decided to revise it to bring it in line with the present practices being followed by the Indian Industry.

In this revision, the following modifications have been incorporated:

a) References to additional Indian Standards have been incorporated.

b) General construction features have been modified.

c) Figures 1 and 2 have been modified.

An analysis of a survey undertaken in the units of forging industry in India revealed that the low fuel utilization efficiency of the forging furnaces was due to:

a) diversity in the shape and design of these furnaces,

b) inappropriate use of refractories,

c) inadequate insulation,

d) deficiencies in burning equipment used,

e) lack of proper recording and control instrument,

f) lack of waste heat recuperation, and

g) poor maintenance.

Due to these factors the fuel efficiency of most of the existing forging furnaces varied from 6 to 10 percent as against an achievable 30 to 40 percent.

This standard highlights the essential parameters which go together in building up an efficient furnace not only from the point of view of energy utilization but also from the point of view of decreasing cost of production, maximizing throughput utilization, easy maintenance, minimizing the down-time of a furnace, etc.

In the formulation of this standard, assistance has been derived from 'Guidelines for increasing the efficiency of box type forging furnaces' prepared by the Energy Conservation Division of the Directorate General of Technical Development, Government of India.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2:1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

AMENDMENT NO. 1 AUGUST 2011
TO
IS 9977 : 1988 DESIGN AND CONSTRUCTION OF BOX TYPE FORGING FURNACES — GUIDELINES

(First Revision)

(*Page* 1, *Table* 1) — Add following Note at the end of the table:

'NOTE — In case of gaseous fuel the consumption can be worked out on the basis of its calorific value.'

(*Page* 2, *clause* **6.1**) — Add the following at the end of last sentence:

'Skin temperature/shell temperature (except roof) shall not exceed 60°C above the ambient temperature. For openings or burner areas, skin temperature/shell temperature is to be measured 1 m away from the respective areas. Roof temperature will be 80°C above ambient temperature. For calculation purpose ambient temperature is to be considered as 40°C.'

(*Page* 2, *clause* **6.2.5**) — Substitute the following for the existing sentence:

'Burner quarls are to be constructed from the refractory having an alumina range 50-90% depending on the use of temperature.'

(*Page* 5, *clause* **8**, *line* 2) — Substitute '80-100 kg/T material depending on the size and capacity and loading pattern of the furnaces for reference charge and reference cycle' *for*. '40 to 50 kg/T of material'.

(*Page* 6, *clause* **10.1**) — Add the following at the end of the last sentence after the words 'Low Pressure Burner'.

'Mass Flow based Temperature Control is to be followed when preheated combustion air is used from the recuperator.'

(*Page* 6, *clause* **10.3**, *Title*; and *lines* 9 *and* 10) — Substitute the words 'Furnace Pressure Indicator/Controller' *for* 'Furnace Pressure Indicator;' and 'indicator for the furnace pressure'.

(*Page* 6, *clause* **10.5**) — Add following new clause 11 at the end:

'**11 Gas Firing System** — For gas firing system the following are to be included:

- Gas Train Safety Equipment
- Flame Monitoring & Auto Ignition System for safe and reliable operation'

(MTD 26)

Reprography Unit, BIS, New Delhi, India

Indian Standard

DESIGN AND CONSTRUCTION OF BOX TYPE FORGING FURNACES — GUIDELINES

(First Revision)

1 SCOPE

This standard covers requirements for box type forging furnaces.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
2042 : 1972	Insulating bricks (*first revision*)
2062 : 1992	Steel for general structural purposes (*fourth revision*)
4813 : 1980	Chemically bonded chrome-magnesite refractories for general purposes (*first revision*)
6533 (Part 2) : 1986	Code of practice for design and construction of steel chimneys: Part 2 Structural aspects (*first revision*)
8154 : 1976	Preformed calcium silicate insulation (for temperatures up to 650°C) (*first revision*)
8183 : 1993	Bonded mineral wool (*first revision*)
8849 : 1991	Glossary of terms relating to fuel fired industrial furnaces (*first revision*)
9010 : 1978	Super heat duty fireclay refractories
9428 : 1993	Preformed calcium silicate insulation (for temperatures up to 950° C) (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 8849 shall apply.

4 SIZES

4.1 The various sizes of the box type forging furnaces covered in this standard are given in Table 1.

4.2 The average load on hearth of the furnace shall be within the range 180-300 kg/m^2.

4.3 Combustion Volume

The combustion volume of the furnace shall be approximately 385 × 1 000 kcal/m^3/h.

5 GENERAL CONSTRUCTION FEATURES

5.1 Furnace Shell

The furnace shell shall be constructed of steel plates of 6 mm thickness and reinforced by structural steel sections conforming to IS 2062.

5.2 Foundation

Care should be taken with respect to the furnace foundation which should be isolated from the forging hammer/press foundation to prevent any vibration being transmitted to the lining of the furnace. This will considerably increase the life of the lining of the furnace.

Table 1 Sizes of Box Type Forging Furnaces

(*Clause* 4.1)

Sl No. (1)	Average Output kg/h (2)	Hearth Area[1] m^2 (3)	Maximum Billet Section mm (4)	Maximum Weight of Billet kg (5)	Fuel Oil Consumption[2] kg/h (6)
i)	100	0.5	75	5	10
ii)	250	1.25	75	5	25
iii)	500	2.5	100	10	50
iv)	750	4.0	150	40	75
v)	1 000	6.0	200	75	100
vi)	1 500	10.0	250	150	150
vii)	2 000	12.0	250	250	200

[1] Typical width twice the depth or *vice versa*.

[2] Oil consumption indicated is on the basis of the continuous operation at maximum temperature of 1 250°C on full effective hearth utilization. Oil consumption would be more where furnaces are frequently operated from cold conditions.

5.3 Doors

To conserve fuel, doors should be operated only when necessary. Permanent doors/slot openings may not only increase the fuel consumption by approximately 10 percent but also adversely effect the metallurgy of the feed stock. Flame curtains/heat shields/multi-doors combined with correct furnace pressure control would considerably improve the performance of the furnace. Doors and door frames shall be constructed with steel plates and stiffened with structural members conforming to IS 2062. Doors and doors opening periphery should be fitted with heat resistant cast iron. Pneumatic or hydraulic actuation or mechanical locking arrangement shall be used to press the door against the furnace structure in closed position.

5.4 Roof

It is economical to use arched roofs up to a span of 3 metres. For longer spans hanging roof is more economical.

5.5 Flue Gas System

Flue gas system should be designed to maintain correct pressure inside the furnace. Down draft flue system with chimney and damper plate arrangement in between the furnaces and chimney shall be installed to maintain correct positive pressure inside the furnace. The height of the chimney shall be designed based on the draft required and considering the regulations of Pollution Control Norms. The chimney shall be designed as per IS 6533 (Part 2).

5.6 Pressure Regulating Valve

Pressure regulating valve may be provided to ensure constant pressure of fuel at the burner. Fuel supply at the burner at constant pressure helps in ensuring proper combustion.

6 LINING

6.1 Considering the operating temperature of 1 200°C for the forge furnaces, the refractory and insulation lining shall be provided for withstanding the temperature of around 1 350-1 400°C. The thickness shall be selected in such a way that skin temperature/shell temperature shall not exceed 60°C above the ambient temperature.

6.2 The typical refractory lining at various positions of the forge furnaces is given in **6.2.1** to **6.2.5**.

6.2.1 *Side Walls*

The working layer shall be made of 230 mm thick super heat duty fireclay bricks conforming to IS 9010. The insulating layers shall consist of 113 mm thick insulating bricks conforming to Type 2 of IS 2042 followed by 50-100 mm thick calcium silicate block conforming to IS 8154 or IS 9428. Alternatively, mineral wool slab conforming to IS 8183 may be used.

6.2.2 *Hearth*

The working layer of the hearth shall be made of 113 mm thick chrome-magnesite bricks conforming to IS 4813. This shall be backed by 150 mm thick fireclay bricks conforming to IS 9010. The insulating layers shall consist of 113 mm thick insulating bricks conforming to Type 2 of IS 2042 backed by 50 mm thick high strength calcium silicate blocks (cold crushing strength 10-12 kg/cm^2) conforming to IS 9428.

6.2.3 *Roof*

The working layer of the roof shall be made of 230 mm thick super duty fireclay bricks conforming to IS 9010. The insulating layers shall consist of 113 mm thick insulating bricks conforming to Type 2 of IS 2042 backed by 50 to 75 mm thick calcium silicate blocks conforming to IS 9428.

6.2.4 *Doors*

The working layer of the door shall consist of 113 mm thick hot face insulating bricks conforming to Type 1 of IS 2042. The insulating layers shall consist of 75 mm thick insulating bricks conforming to Type 2 of IS 2042 followed by 50 mm thick calcium silicate blocks conforming to IS 9428.

6.2.5 *Burner Quarls*

The burner quarls should be constructed of sillimanite bricks.

6.3 The mortars shall be made out of equivalent quality of different types of bricks. The physico-chemical properties of the mortars shall be nearest to the physico-chemical properties of the bricks.

6.4 While constructing a furnace inner lining, suitable allowance should be made for expansion and contraction of walls, roof, hearth, etc. The furnace door lining should be made in such a way that when the doors are closed, the lining should be completely flushed with the lining around the door opening in the furnace body, leaving practically no gap to escape of hot gases from the furnace.

7 COMBUSTION SYSTEM

7.1 Fuel Oil System

In this system, generally the ring main system is adopted. Flow line diagram of typical ring main system is shown in Fig. 1 and Fig. 2. It may be designed for a minimum 2 to 3 times the capacity of the burner. The ring main system should be primed for approximately half an hour before lighting the burner.

7.1.1 It is advisable to have fuel oil at the correct pressure and viscosity at the tip of the burner. The furnace oil available in India needs to be heated to approximately 90 to 100°C to obtain optimum viscosity

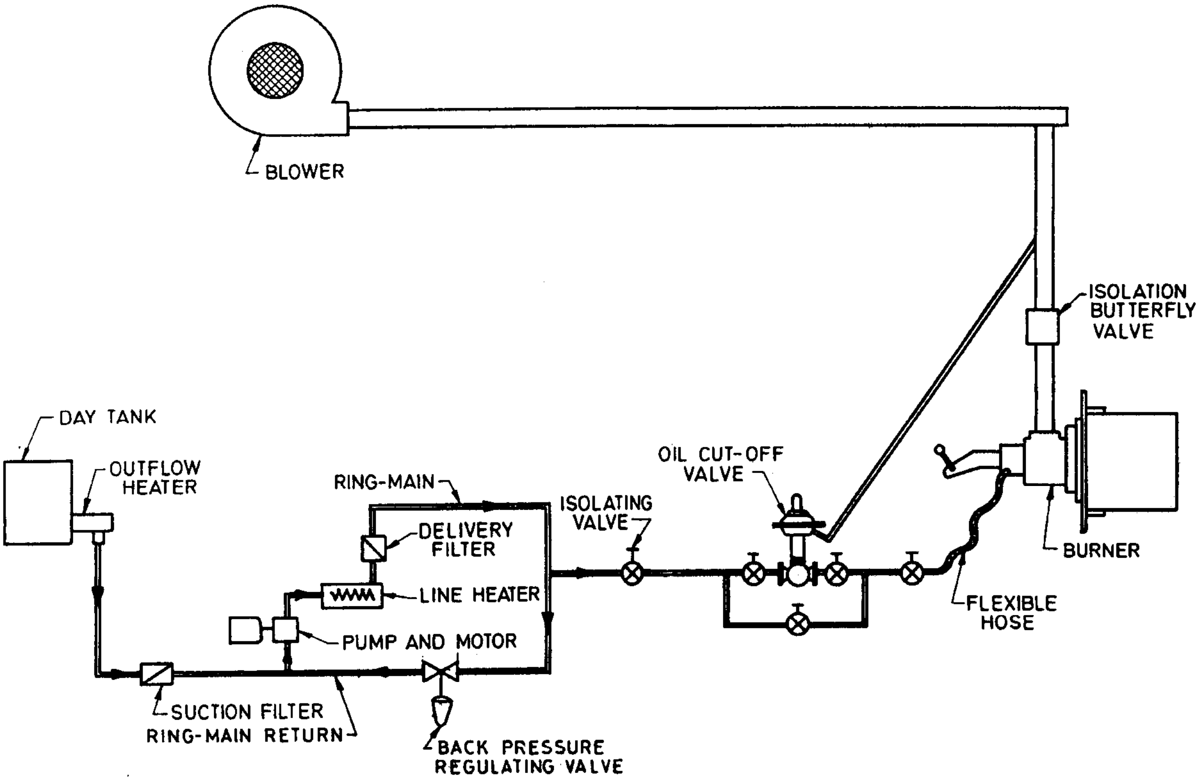

FIG. 1 SCHEMATIC DIAGRAM OF AIR AND OIL PIPING FOR SELF-PROPORTIONING BURNER

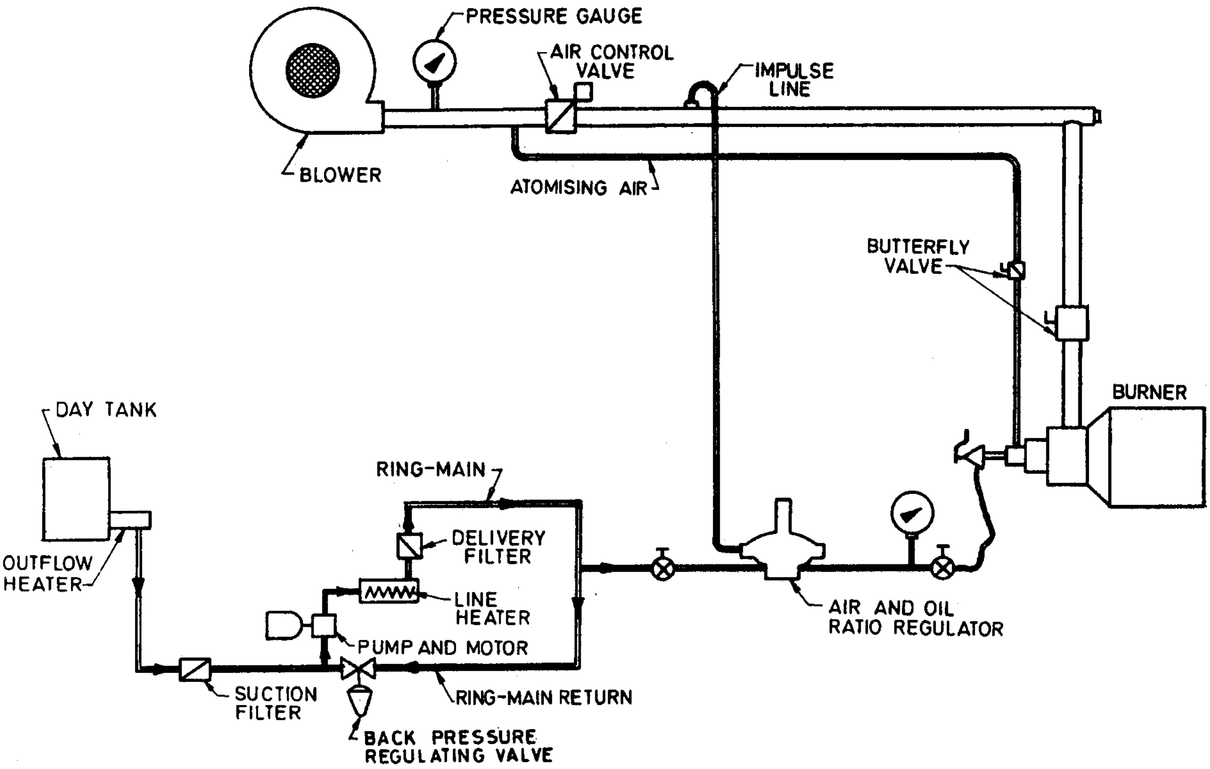

FIG. 2 SCHEMATIC DIAGRAM OF AIR AND OIL PIPING FOR BURNER WITH EXTERNAL AIR/OIL RATIO REGULATOR

(generally 100 seconds on Redwood I scale) at the burner. LSHS oils may have to be heated up to 120°C. Depending upon the grade of fuel oil, system of storage and distribution to individual furnace/burner, provision of steam/electric heater coil and outflow heater in the storage/service tank with thermostatic control may be necessary. Piping between storage/service tank and individual burner should be properly lagged. In case of LSHS oil, heat tracing of the piping network is recommended besides other precautionary measures like flushing the ring system with light oil before shutting off the furnace.

7.1.2 *Burners*

Burners are selected based on available fuel (oil or gas), fuel oil grade, type of fuel gas (also cleanliness and calorific value of gas) and the temperature of air for combustion. Accordingly, burners can be chosen exclusively for oil firing, gas firing or combination burner for firing either oil or gas as fuel.

In case of oil burners, the fuel oil need to be vaporized before burning. Most industrial oil burners use two steps to get the fuel oil into combustible form—atomization plus vaporization. Burners selection can be either:

a) *Self-proportioning burners* — In these burners, oil and air flow can be preset to a definite ratio. It is then necessary to operate only one lever to change simultaneously oil and air. It is possible to connect levers of a number of self-proportioning burners with linkage rod to a common control actuator (electric/pneumatic) for operating the furnace on automatic controls. Since, in such burners, there is no separate entry for atomizing air (*see* Fig. 1), the extent of air preheat should not exceed 200°C in case there is a recuperator in the system.

b) *Low air pressure burners* — These burners also need fuel oil station as well as air blower like self-proportioning burners. However, both air and oil flow control valves are separated and they need to be regulated either by direct linkage or by external ratio regulator. In low air pressure burner system, atomizing and combustion air have separate piping connection to the burner (*see* Fig. 2) which allows higher combustion air preheat in case of a recuperator in the system. Atomizing air pressure and flow rate is generally kept constant at the burner and atomizing air should not be preheated.

c) *High pressure air (compressed air) or steam atomized burners* — These burners can also be used, if such utilities are easily available in the shop.

d) *Fully automatic burners (package burners)* — These burners have built-in oil pump, preheater, blower and are switched on electrically, starts-up and continues in operation at preset oil consumption or by flame modulation to satisfy the heat demand. Safety devices for emergency shut-off are also built-in which call for manual resetting before restart. Such burners are more suitable for ovens, package boiler and may be as single burner application in smaller box forging furnaces.

In case the available fuel is gas, the following types may generally be used:

a) *Premix gas burners*—In premix gas systems, the primary air and fuel gas are mixed at some point upstream from the burner ports by an inspirator mixer, an aspirator mixer or a mechanical mixer. The burner proper (nozzle) serves only as a flame holder, maintaining the flame at the desired location.

b) *Nozzle mixing gas burners* — As the name implies, the fuel gas and combustion air do not mix until they leave the port of this type burner. The two fluids are kept separate within the burner itself, but the nozzle orifices are designed to provide mixing of the fluids as they leave.

Periodic changes in the supply of fuel as well as price picture may sometime call for changing of fuels. Hence combination burners for firing either fuel oil or fuel gas are also available for selection.

7.1.3 *Combustion Air Supply*

7.1.3.1 Fully automatic burners do not require separate combustion air blowers.

7.1.3.2 In case of low pressure burners, self-proportioning burners as well as gas burners, it is necessary to provide combustion air blower. The capacity of the combustion air blower for oil burners should be about 15 Nm^3/kg of oil consumption (this includes 10 percent excess air) at pressure varying between 6-10 kPa (600-1 000 mm W.G.) depending upon the recommendation of the burner suppliers. The capacity of the combustion air blower should be 30 percent higher than the theoretical air requirement.

7.1.3.3 Use of recuperators will increase the combustion air blower pressure by 1-2.5 kPa (100-250 mm W.G.).

7.1.3.4 Provision should exist for periodic checking of combustion air pressure.

7.1.4 *Atomizing Air Supply*

For low pressure air atomized burners, the air for atomizing the fuel oil can be supplied by a common blower for providing both atomizing and combustion air or by two separate blowers.

For self-proportioning burners, the air for atomizing the fuel oil is supplied by a common blower selected based on the total air (combustion plus atomizing) requirement.

7.2 Fuel Gas System

7.2.1 It is necessary to have fuel gas as well as the combustion air at the burner. In most of the cases fuel gas is available at a higher pressure than required and hence it is necessary to use the pressure regulating valve to ensure that the gas pressure at the burner will remain constant irrespective of the flow rate of the gas. A typical flow line diagram for air and gas piping system is shown in Fig. 3. Fuel gas supply to the forge shop will have an isolation valve at the shop entry. Provision of purging the gas line with steam or nitrogen should be provided. Necessary purging connection and bleeders should be incorporated.

7.2.2 In case coke oven gas is used in forge shop box type furnaces, following facilities should be provided:

a) Isolation facility by providing water filled U-seal, valve and blanking and deblanking facility.

b) Filtering facility to remove tar and other impurities which may clog burners.

7.3 Safety Precaution

7.3.1 Unburnt fuel in the furnace is safety hazard. It is, therefore, advisable to incorporate safety shut-off valve just before the burner. The safety shut-off valve may be either solenoid type to interrupt full supply in case of power failure or diaphragm type to interrupt fuel supply in case of low combustion air pressure or low fuel pressure.

7.3.2 Safety shut-off valve need not be incorporated in the fuel line when operating fully automatic burners as they already have the necessary built-in safety measures.

7.3.3 Mesh type flame arrestor may be incorporated before the burner in the gas line to prevent any propagation of the flame in the pipe line in case of back firing.

7.3.4 Before priming the fuel gas line, all joints in the pipe line should be carefully checked with soap solution for any leakage. This may be repeated regularly to ensure gas-tight piping.

7.3.5 All safety valves for the fuel gas line should be of tight shut-off type.

7.3.6 The furnace should be purged thoroughly to remove all the combustibles and other gases from the furnace before lighting the burners.

8 SPECIFIC FUEL CONSUMPTION

Well designed furnaces with recuperators normally have fuel consumption of 40 to 50 kg/t of material. Out of this about 20 kg/t material is required for heating steel and rest are losses through the exit flue gas, steady heat flow through furnace innerlining, losses due to openings, etc. This, however, can be achieved when the furnace is operating at rated capacity continuously and is well maintained.

9 RECUPERATORS

9.1 The incorporation of a recuperator depends primarily upon the extent of utilization of the furnace. In general, it is economical to use a recuperator.

9.2 Recuperator may be provided not only for pre-heating the combustion air but also for fuel gas with low calorific value normally obtained from coal gasification plant.

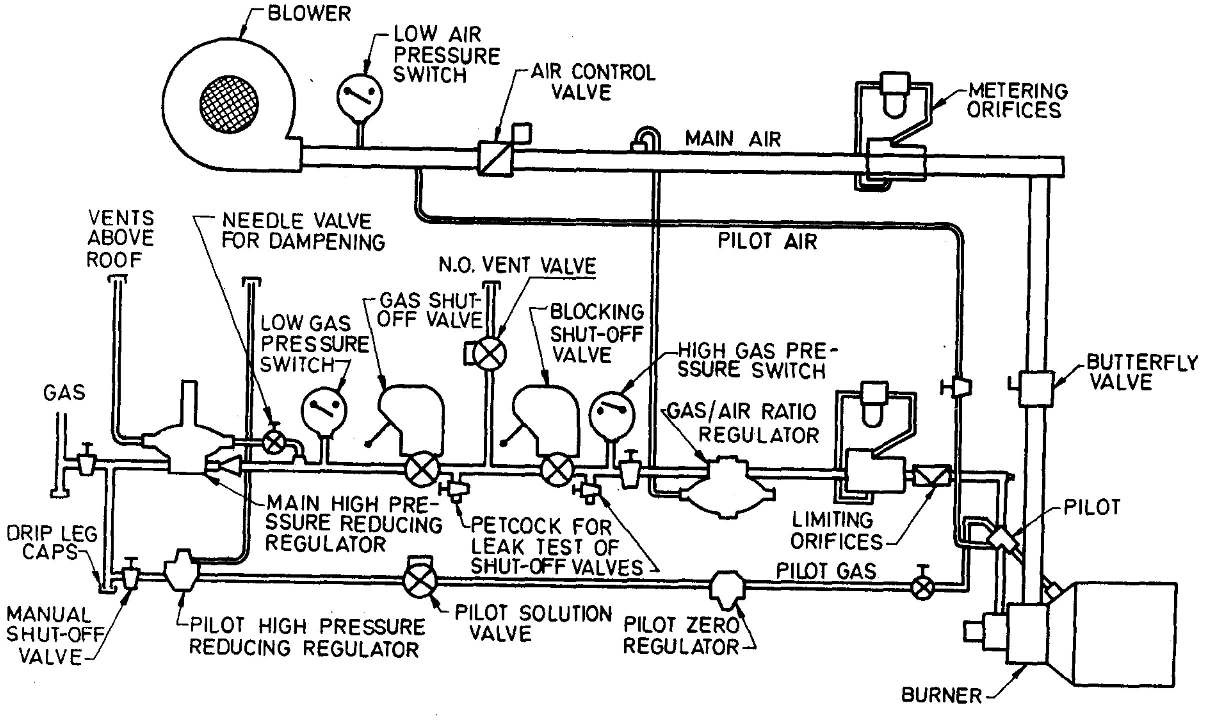

FIG. 3 SCHEMATIC DIAGRAM OF AIR AND GAS PIPING FOR GAS BURNER WITH AIR/GAS REGULATOR

9.3 In forging furnaces, the fuel savings that may be obtained with different degrees of pre-heat of air (under ideal operating conditions and continuous operation), based on flue temperature of 1100°C, are shown below:

Pre-heat	*Fuel Saving*
200°C	12-14 percent
300°C	17-21 percent
400°C	22-27 percent

9.3.1 A preheat of 300°C is generally preferred though the maximum may be up to 450-500°C.

9.4 For furnaces with outputs up to 500 kg/h, it is advisable to use the radiation recuperator mounted directly on the roof of the furnace. For furnaces with higher outputs the convection/radiation recuperator may be located in flue, underground or overground, depending upon the layout of the flue system.

9.5 By-pass may be provided on combustion air and/or flue gas side for starting up as well as maintenance.

9.6 For efficient use of the recuperator, it is essential that elements are kept clean by periodic servicing.

9.7 Adequate precautions may be taken to provide for expansion/contraction in the recuperators as well as hot air/gas piping.

9.8 When using a recuperator, it is recommended to have alarm system to indicate overshooting of flue gas temperature above the specified limit near the inlet of the recuperator and recuperator protection through hot air bleed or through dilution air should be provided.

10 INSTRUMENTATION

In order to achieve uniform heating of the charge stock, optimum utilization of the charge stock and fuel being used and also to safeguard trouble-free operation of the furnace over a long period of time, the parameters detailed in **10.1** to **10.5** are recommended to be monitored/controlled in a fuel fired box type forging furnace.

10.1 Temperature Measurement/Control

For forging furnaces, it is recommended to use Pt-Rh thermocouples for measuring the temperature. The thermocouple tip should be brought inside the furnace by atleast 100 mm from the inside walls of the furnace. The thermocouples may be connected either to a temperature indicator (in case of manual controlling of furnace temperature) or to a temperature indicating controller (in case of automatic control of furnace temperature) which may operate either the fully automatic burner or the actuator motor of the self-proportioning burner or low pressure burner.

10.2 Temperature Recorder

It is recommended that all furnaces, whether manually controlled or automatically controlled, should have a temperature recording system.

10.3 Furnace Pressure Indicator

In order to ensure efficient operation of the furnace, it is recommended that the furnace pressure should be controlled carefully and maintained slightly positive (0.25 to 0.5 mm W.G.) at hearth level. The furnace pressure can be controlled, both manually and automatically, by adjusting the damper in the flue exhaust duct/channel from the furnace. It is recommended that fuel fired box type forging furnaces should be provided with a suitable indicator for the furnace pressure.

10.4 Flow Meter

To keep a close control over the fuel oil/fuel gas fed to the furnace, an oil/gas flow meter should be incorporated.

10.5 Gas Analyzer

Flue gas should be analyzed preferably once a shift for steady working conditions, and more often otherwise, with portable oxygen analyzer to ensure correct combustion condition inside the furnace.

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